Composite Dome and Polar-Boss Leakage Validation

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The goal of this research project is to demonstrate the design, analysis, manufacture, and test of a composite spherical dome cap and polar-boss assembly on the Cryostat Test Facility. The dome cap will be designed for 75-pounds-per-square-inch internal pressure with liquid hydrogen and a circular cutout to accept candidate polar-boss assemblies. The composite dome cap will be fabricated using a combination of fiber placement and hand layup in MSFC's Productivity Enhancement Complex. The major objective of the research is to demonstrate an acceptable level of hydrogen leakage for a composite dome and metallic polar-boss assembly subjected to thermal and pressure cyclic loading.

The effort to significantly reduce launch vehicle weight while still meeting mission objectives has led to increasing use of high-modulus, high-strength composite materials for major structural elements. Under the National Aerospace Plane program, a rectangular composite liquid-hydrogen tank was designed and built to demonstrate that composite materials can be used to manufacture cryogenic tankage. However, most launch vehicle cryogenic tanks are cylindrical and contain dome/polar-boss assemblies which enclose the tank ends, as opposed to the flat, square bulkheads used on the rectangular National Aerospace Plane tank. In order to obtain credible membrane permeability data, a polar-boss joint with minimal leakage would be necessary. During the 1995 fiscal year, six subscale composite tanks were tested with liquid nitrogen to determine the integrity of the polar-boss/dome joint. The first five test tanks leaked during or after the first cryogenic pressure cycle. Although the test of the sixth configuration provided no detectable leakage with bubble solution after the first cycle, further pressure/thermal cycling compromised the integrity of the polar-boss/dome joint, rendering the joint unacceptable. Therefore, the current investigation will determine an acceptable polar-boss/composite dome joint configuration.

Once the composite spherical dome cap has been fabricated, the cap will be installed along with a containment shell on the Cryostat Test Facility. Phase I testing will consist of liquid-nitrogen/gaseous-helium testing to characterize the leakage associated with the dome cap installed in the facility. Once phase I testing is complete and the data have been analyzed, a circular cutout will be machined in the top of the composite dome cap to accept candidate polar-boss configurations. Phase II testing will follow the same testing plan as phase I in order to characterize the polar-boss leakage, and will include the testing of three to four polar-boss configurations until an acceptable configuration is determined. Once an acceptable polar-boss configuration has been determined, liquid-hydrogen testing of the polar-boss/dome-cap joint for leakage will be completed. All of the testing is based on availability of the Cryostat Test Facility in the West Test Area at MSFC.

This research will provide NASA with a valuable technology for the Reusable Launch Vehicle initiative. At the time this article was written, no commercial or government agency had proven an acceptable metallic polar-boss and composite tank interface. Once proven, this technology will directly benefit the industrial partners working toward a reusable launch vehicle by providing a data point for acceptable joint leakage.

Sponsor: Center Director's Discretionary Fund

Industry Involvement: Thiokol Corporation